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Shock Test Machine User's Guide

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13. ABSTRACT *(Maximum 200 words)*

This report provides a general description of the IMPAC66 HVA Shock Test Machine, safety guidelines, and calibration data. The report is intended to quickly familiarize the user with the shock test machine operations and typical data. A brief discussion on data interpretation and the criteria used when examining the data are included. Additionally, the appendix contains simple verification tests to ascertain that the accelerometers are generally functioning properly.

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1. INTRODUCTION

This brief collection of notes is intended to supplement the MTS Systems Corporation, Minneapolis, Minnesota, reference manual entitled "Instruction Manual, IMPAC 66 HVA Shock Test Machine" (MTS reference manual), and indeed many of the safety suggestions and operating procedures are found in the manual. The goal of these notes is to: reiterate the salient safety procedures, quickly describe the essentials of what is necessary for testing, discuss some common problems encountered, and familiarize the user with the various aspects of the machine. If questions arise concerning safety or any of the general operating parameters of the machine the reader is encouraged to consult the MTS reference manual or the Ballistic Research Laboratory (BRL) Launch and Flight Division (LFD) Standard Operating Procedure (SOP) 385-1.

2. SHOCK TEST MACHINE SAFETY

"Shock machines are inherently dangerous. Extreme caution should be used when installing programmers or adjusting switches. Safety bars should always be installed to support the table when working near the machine..." (MTS Reference Manual).

When a particular deceleration pulse is desired, various programmers (hereafter referred to generically as "deceleration materials," or "dampers") are used. These damper materials may consist of felt, plastic, and even high-pressure gas. Installation of these dampers hold the potential for injury from the drop table. They are installed between the anvil (reaction mass) and the drop table. The use of these damper materials allows the impact of the drop table to be controlled so that no free-flying parts are produced, and the desired decelerations are obtained. Figure 1 shows the machine layout, with nomenclature, of the various shock-test machine paraphernalia used here at BRL, Building 120. Safety bars, which prevent release of the drop table, are mandatory when installing these deceleration devices. These "U-channel" shaped bars are approximately 20-cm long and are placed longitudinally around the guide rods depicted in Figure 1. The plastic deceleration materials as well as the high-pressure gas deceleration cylinder (known as the "universal programmer") must be screwed in place, which requires working directly beneath the drop table. Positioning felt dampers is the

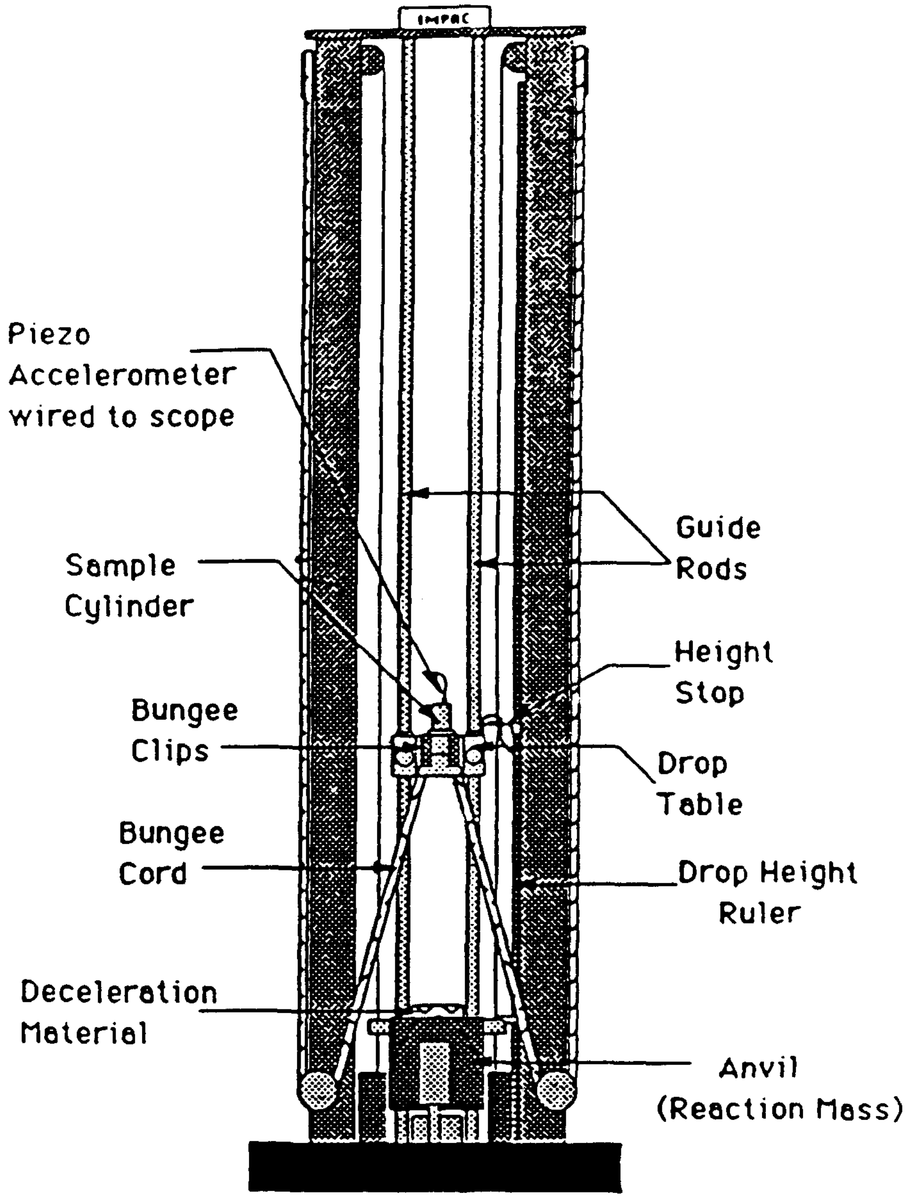

Figure 1. Impac Machine Layout.

exception. They are customarily installed by sliding a suitable thickness felt section between the anvil and the drop table. Since these dampers are not screwed into place, the operator is not forced to work under the drop table, and hence, safety bars are optional. The default position oı the drop table should be at rest against the anvil. In addition, bolts on the anvil and drop table faces should be checked to verify tightness after each drop.

Operational safety consists of a few basic "common sense" type of checks: Ensure that the specimen to be tested is securely attached to the drop table. Verify that all electrical connections are also firmly attached. Loose components give poor data and can be dangerous if they become projectiles. Verify the height stop is at the level desired. Drops generate forces on the deceleration materials. If these forces are too great, degradation of the plastic programmers may occur. Closing the armor-plated door is also mandatory when firing.

Ear protection is desirable for prolonged machine use or when the machine is operated from large drop heights. Releasing the drop table from drop heights less than 50 cm onto a plastic damper produced noise that was below occupational safety limits, but headphone ear guards are recommended for larger drop heights.

The Impac shock test machine uses high-pressure gas to raise and lower the drop table and anvil. The system will not function unless a pressure of 6.89 MPa is present in the gas lines leading to the machine. If the pressure is < 6.89 MPa, the "on" light on the panel will simply remain unlit. When testing is complete, the gas cylinder valves should be turned off, and the gas trapped between the regulator and the machine vented by the black release valve located on the regulator.

3. OPERATIONS

Several operational guidelines are worth noting: As per LFD-SOP 385-1, two persons are required to be present during testing. One typically monitors the Impac shock machine functions, while the other assures that the necessary data is being acquired. Assuming the deceleration material has already been chosen and installed, a typical firing sequence is as follows:

(1) Activate gas pressure system.

(2) Secure specimen on drop table.

(3) Set drop height.

(4) Set "Arm/Disarm" switch to "Disarm."

(5) Raise table via "Raise" button until height stop is activated.

(6) Lower the anvil via the "Lower" button.

(7) Set "Arm/Disarm" switch to "Arm."

(8) Depress both fire buttons simultaneously.

The drop table is never to be dropped onto a bare anvil table (some sort of deceleration material should always be present). Once the raised drop table contacts the height stop switch, the drop table can be lowered two ways: one, by firing the system; or two, by deactivating the height stop switch by adjusting it further up the drop height ruler and raising the anvil until it contacts the drop table, at which point the two can be lowered simultaneously. This note is important because occasionally drop height changes are requested after the drop table has been raised.

At very large drop heights (> 1.52 m), the bungee cords have a tendency to disengage from their channels during firing. Aluminum angle sections may be attached to the drop table to prevent bungee cord dismount.

Every deceleration material has its impact limits beyond which significant resonance will occur. Data traces must be monitored to assure that the data obtained is representative of the acceleration desired. Placing thin felt sections under the test specimen and then clamping the arrangement tightly serves to reduce excess vibrational effects, to some extent. The height where large vibrations occurred was determined empirically. Unfortunately some interpretation of what constitutes acceptable data is necessary. The criterion used during the tests at LFD was that the portion of the trace with rapid oscillations (ringing) should have oscillation amplitudes that are no greater than the initial pulse. Most of the testing done thus far has used the felt dampers.

Three different damper materials can be used in the Impac 66 HVA Shock Test machine. The Universal Damper uses pressurized air as the damping material. Three distinct types of

urethane dampers with varying stiffnesses are also available. Their degree of stiffness is quantified by a Duro-Shore A number. For the red dampers, the number falls between 90–100; for black, 60–70; and for green 35–45. These dampers can be combined in series to yield further varying stiffnesses.

The deceleration materials and/or methods that follow are recommended in ascending order of drop height. For "low" values of acceleration, those on the order of 0–500 g's*, the universal programmer is recommended. This universal programmer is able to produce a variety of pulse shapes depending on its cylinder pressure. If a specific wave shape, such as, a trapezoidal deceleration profile, is desired, this attachment is best suited to produce it, as opposed to the other dampers. The next choice of deceleration materials is the plastic dampers. These materials are durable and built for quick fastening to the drop table and/or anvil. Their range of decelerations spans 500–5,000 g's. These materials are color-coded for stiffness—the red, being the most stiff, and the green being the least. In addition, they may be combined to form intermediate stiffness dampers. The highest acceleration level dampers are the felts. White, high-density felt of varying thicknesses can withstand deceleration levels of up to 30,000 g's, although in practice, "good" data has only been obtained up to 16,000 g's. Table 1 summarizes these materials.

Table 1. Damper Material Limits

Damper	Shock Level 1,000 g's	Normal Pulse Duration (ms)
Universal	0–.50	3.0–7.0
Red plastic	2–5	.5–1.0
Black plastic	2–4	.7–2.0
Green plastic	1–2	.9–1.5
Thin felt	12–30	.1–.9
Thick felt	20–30	.1–.9

*Note: "g" is the acceleration on earth due to gravity (roughly 9.8 m/s^2).

Shock-test instrumentation must also be carefully handled during testing. Particular care should be exercised when mounting the accelerometer to the test specimen fixture. The prescribed torque is slightly more than "hand tight" (around .68–1.13 Nm). The accelerometers used in this testing have a 50,000-g deceleration limit. This is well beyond what has been achieved on the Impac 66 shock test machine and the accelerometer should function for all drop heights.

Some aspects of shock testing make consistency difficult to obtain. Discussions with industry technicians revealed that normal test results using deceleration gages in shock test machine operations could be expected to differ up to 15% from drop to drop. Presumably this is due primarily to the impact with the damper material and anvil. As an example, thick felt section properties change after several drops. In the case of the 2.54-cm-thick felt damper its thickness was reduced 25% after 50 to 75 drops. Its density was increased, and hence, it became a stiffer damper. The change in the deceleration is small but detectable. High-density felt, whose density changes little under repeated shocks, is recommended if smooth deceleration pulses cannot be obtained. Figures 2 and 3 show expected deceleration vs. drop height. These graphs are intended as a tool to suggest probable drop heights to produce the necessary deceleration levels.

4. MAINTENANCE

The maintenance of the Impact machine is relatively minimal. The guide rods required daily lubrication with a light grade oil when the machine is used frequently. Inadequate lubrication can result in anomalous readings and excess friction and wear on the drop table bushings. The bungee cords are also to be kept free from oil as they tend to deteriorate rapidly if oil-soaked. The pressure from the universal damper should be vented in the same manner that the high-pressure gas system is vented as noted in LFD SOP 385-1. The valve to vent the universal damper is mounted on the control panel. A pressure gage is mounted on the control panel to allow the universal programmer to be monitored.

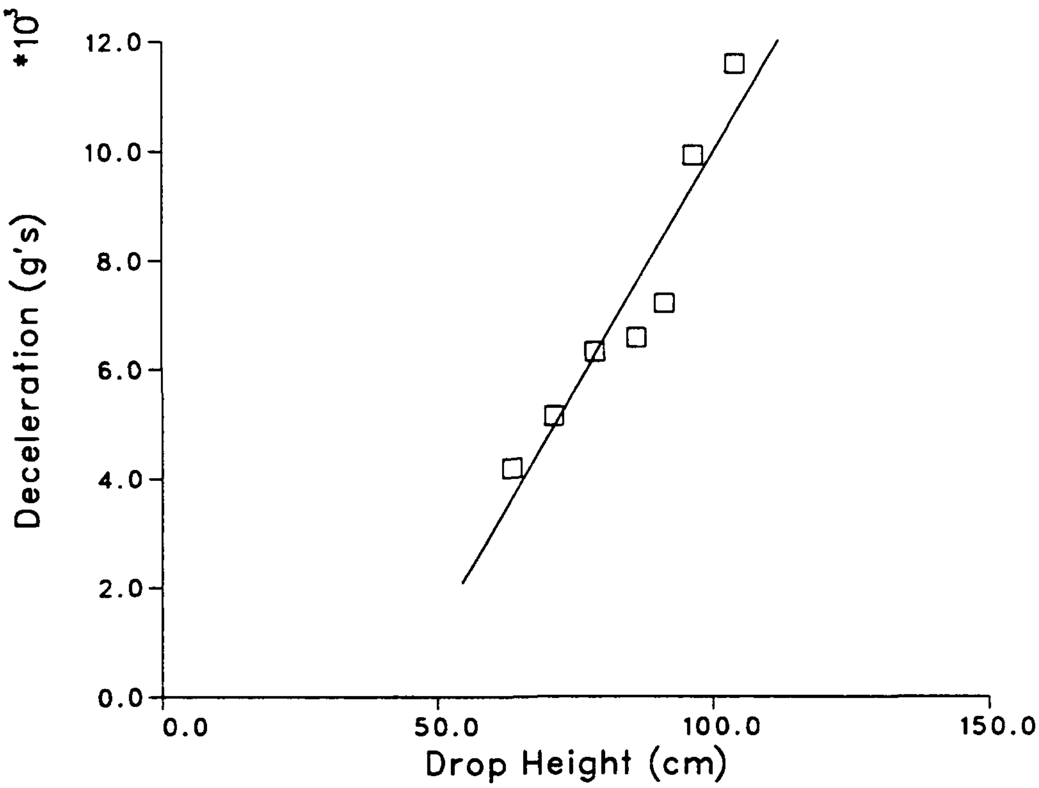

Figure 2. Deceleration vs. Drop Height for Thin Felt (0.64 cm).

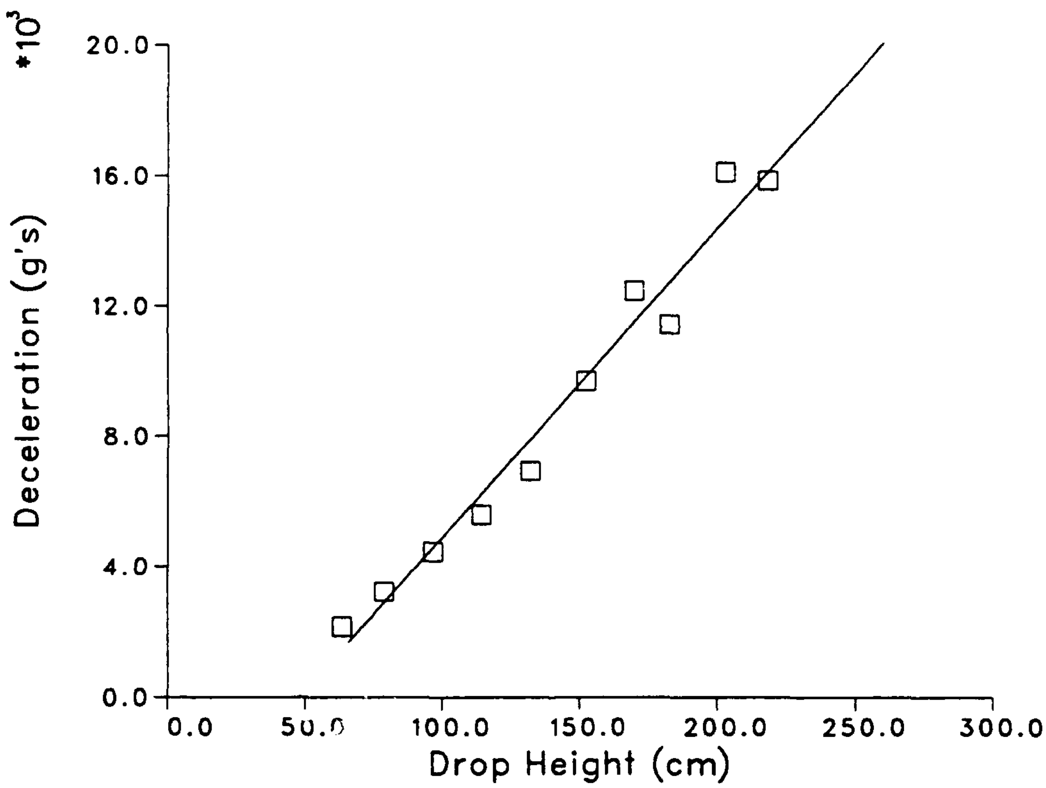

Figure 3. Deceleration vs. Drop Height for Thick Felt (2.54 cm).

APPENDIX:

TABULATED DATA AND ACCELEROMETER CHECKS

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The following tables (A-1 and A-2) give the tabulated values for the graphs in Figures A-1 and A-2. The gage readings are the average of three or more drops at a given height. The vast majority of the drops produced consistent piezoelectric data especially when using the 0.64-cm-thick felt dampers.

Table A-1. Deceleration vs. Drop Height for Thin Felt (0.64 cm)

Drop Height (cm)	Shock Level (g's)
63.5	4,188
71.2	5,141
78.7	6,314
86.4	6,576
91.4	7,204
96.5	9,895
104.1	11,560

To verify the piezoelectric gage output, a mechanical acceleration measurement device was used to produce comparative data. The mechanical copper crusher assembly was mounted adjacent to the piezoelectric gage. This data is seen in Figure A-1. The majority of the data indicated that there was agreement within 15% of the piezoelectric values obtained. Logically the copper crusher deceleration values were smaller than the piezoelectric values. This is due to losses that are incurred as the copper sphere is deformed that do not occur in the electrical output.

The second verification test was to operate the machine in a free-fall mode (without bungee cords), and observe the data traces produced. The data traces can be converted to a deceleration vs. time graph using the conversion factor supplied with the deceleration gage. Once obtained, this graph can be integrated to yield the maximum drop table velocity. Figure A-2 shows the lossless velocities obtained by integrating the deceleration pulses. The result is interesting in that the pulse analysis seems to reveal a 25% loss compared to the ideal velocity. Obviously, the pulse trace will not match the ideal velocity for several reasons. First, the impact between the anvil and the drop table very loosely approximates an elastic

Table A-2. Deceleration vs. Drop Height for Thick Felt (2.54 cm)

Drop Height (cm)	Shock Level (g's)
63.5	2,165
78.7	3,232
96.5	4,450
114.3	5,592
132.1	6,932
152.4	9,682
170.2	12,446
182.9	11,416
203.2	16,065
218.4	15,805

collision. Secondly, the clamped components and the frame of the machine will absorb some of the energy making the collision even less elastic. Lastly, there is some frictional resistance in the guide rods that will cause the drop table to strike the anvil slower than the ideal calculated velocity. The deceleration values obtained are consistent. And the fact that the velocities experimentally obtained are smaller than the ideal calculated velocities indicates that the piezoelectric gage is yielding believable measurements.

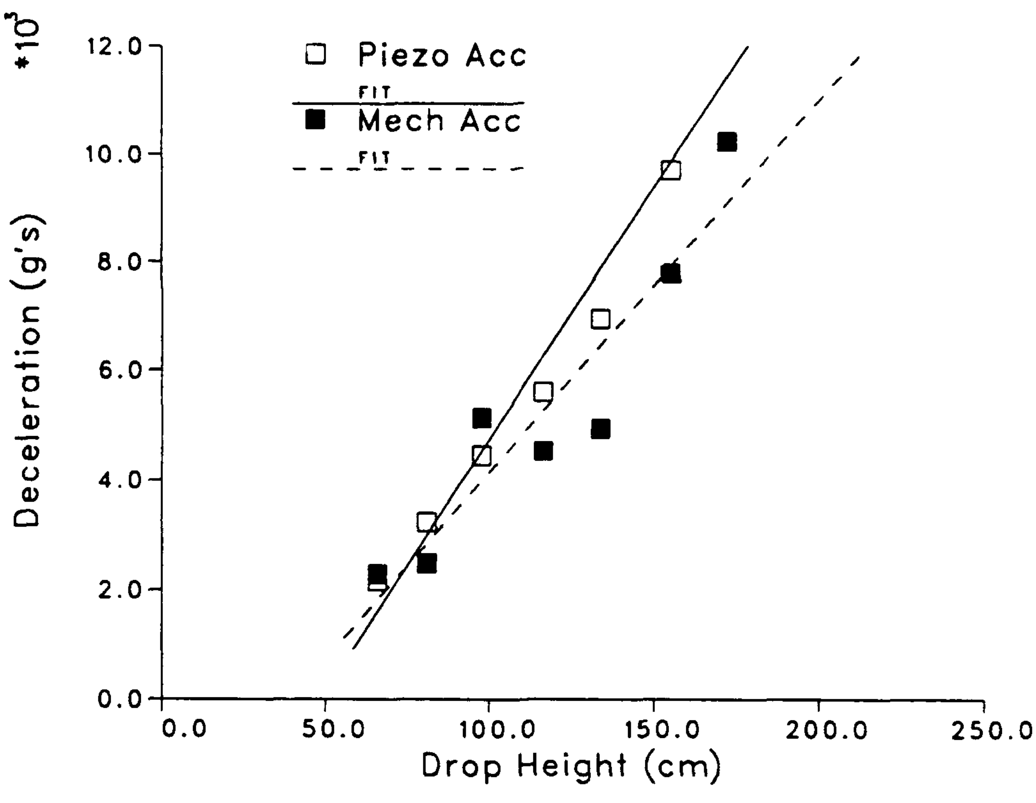

Figure A-1. Piezoelectric and Mechanical Deceleration Data.

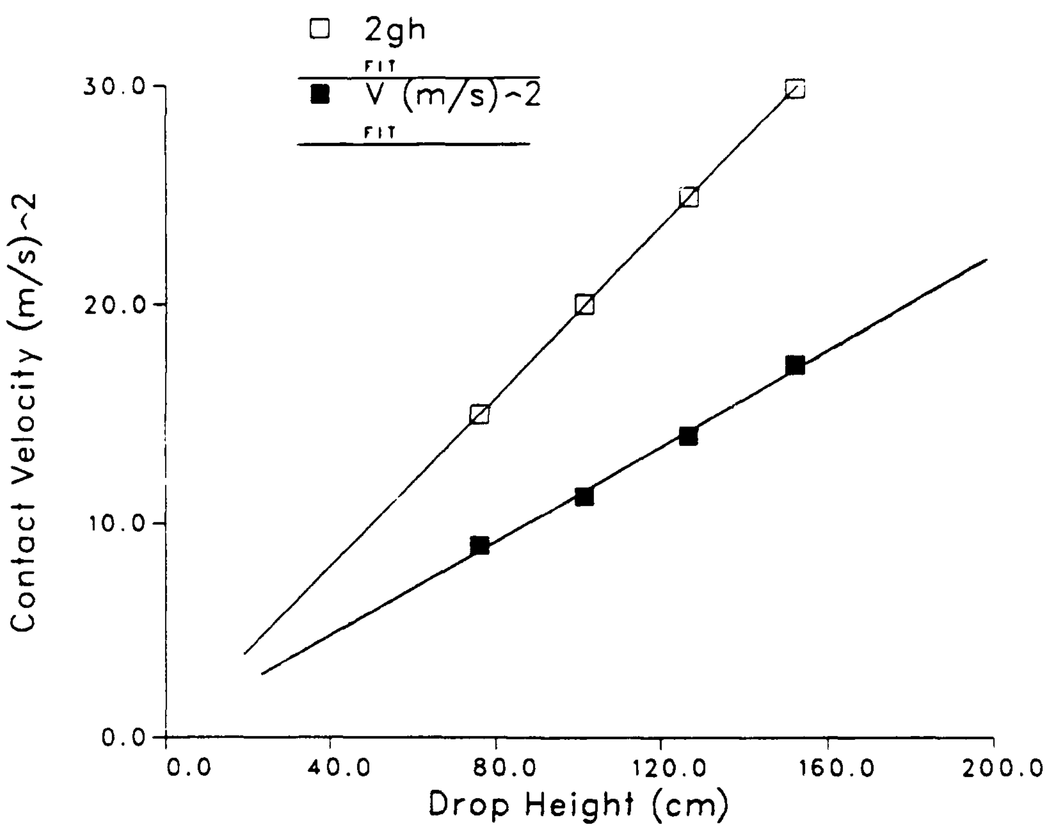

Figure A-2. Free-Fall Velocity and Integrated Deceleration Pulse Measurements.

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